



Year: 2018

Influence of testing parameters on the load-bearing capacity of prosthetic materials used for fixed dental prosthesis: A systematic review and meta-analysis

Özcan, Mutlu ; Höhn, Julia ; Monteiro de Araújo, Gabriela ; Moura, Dayanne Monielle Duarte ; Souza, Rodrigo Othávio Assunção

Abstract: The aim of this study was to systematically review the literature to assess static fracture strength tests applied for FDPs and analyze the impact of periodontal ligament (PDL) simulation on the fracture strength. Original scientific papers published in MEDLINE (PubMed) database between 01/01/1981 and 01/06/2010 were included in this systematic review. Data were analyzed considering the test method (static loading), material type (metal-ceramic-MC, oxide all-ceramic-AC, fiber reinforced composite resin-FRC, composite resin-C), PDL (without or with) and restoration type (single crowns, 3-unit, 4-unit, inlay-retained and cantilever FDPs). The selection process resulted in the 72 studies. In total, 377 subgroups revealed results from static load-bearing capacity of different materials. Fourteen metal-ceramic, 190 AC, 121 FRC, 45 C resin groups were identified as subgroups. Slightly decreased results were observed with the presence of PDL for single crowns (without PDL=1117±215 N; with PDL=876±69 N), 3-unit FDPs (without PDL=791±116 N; with PDL=675±91 N) made of AC, 3-unit FDP (without PDL=1244±270 N; with PDL=930±76 N) and inlay-retained FDP (without PDL=848±104 N; with PDL=820±91 N) made of FRC and 4-unit FDPs (without PDL=548±26 N; with PDL=393±67 N) made of C. Overall, for single crowns, fracture strength of FRC was higher than that of AC and MC; for 3-unit FDPs FRC=C>AC=MC; for 4-unit FDPs AC>FRC>C and for inlay-retained FDPs, FRC=AC. An inclination for decreased static fracture strength could be observed with the simulation of PDL but due to insufficient data this could not be generalized for all materials used for FDPs.

DOI: <https://doi.org/10.14295/bds.2018.v21i4.1652>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-162823>

Journal Article

Published Version

Originally published at:

Özcan, Mutlu; Höhn, Julia; Monteiro de Araújo, Gabriela; Moura, Dayanne Monielle Duarte; Souza, Rodrigo Othávio Assunção (2018). Influence of testing parameters on the load-bearing capacity of prosthetic materials used for fixed dental prosthesis: A systematic review and meta-analysis. *Brazilian Dental Science*, 21(4):470.

DOI: <https://doi.org/10.14295/bds.2018.v21i4.1652>

Influence of testing parameters on the load-bearing capacity of prosthetic materials used for fixed dental prosthesis: A systematic review

Mutlu Özcan^a, Julia Höhn^a, Dayanne Monielle Duarte Moura^b, Gabriela Monteiro de Araújo^b, Rodrigo Othávio Assunção Souza^b

^aUniversity of Zürich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Plattenstrasse 11, CH-8032, Zurich, Switzerland.

^bFederal University of Rio Grande do Norte (UFRN), Department of Dentistry, Division of Prosthodontics, Av. Salgado Filho, 1787, Lagoa Nova, Natal/RN.

Running head: *Load-bearing capacity of prosthetic materials*

Contribution to the paper: Mutlu Özcan and Julia Höhn (Idea, Consulted, evaluated, hypothesis, execution of the search strategy, selection of the studies, and wrote manuscript), Dayanne Monielle Duarte Moura and Gabriela Monteiro de Araújo (execution of the data extraction and wrote manuscript) Rodrigo Othávio de Assunção e Souza (Idea, Consulted, evaluated the results and Proofread the Manuscript).

****Corresponding author at:*** Rodrigo O. A. Souza, DDS, MSc, PhD, Department of Dentistry,
Federal University of Rio Grande do Norte (UFRN)

Address: Av. Salgado Filho, 1787, Lagoa Nova, Natal/RN. CEP: 59056-000

e-mail: rodrigoothavio@gmail.com

Influence of testing parameters on the load-bearing capacity of prosthetic materials used for fixed dental prosthesis: A systematic review

ABSTRACT

Objective: The aim of this study was to systematically review the literature to assess static fracture strength tests applied for fixed dental prostheses (FDPs) and analyze the impact of periodontal ligament (PDL) simulation on the fracture strength. **Material and Methods:** Original scientific papers published in MEDLINE (PubMed) database between 01/01/1981 and 10/06/2018 were included in this systematic review. The following MeSH terms, search terms, and their combinations were used: “Dentistry”, “Fracture Strength”, “Fracture Resistance”, “Fixed Dental Prosthesis”, “Fixed Partial Denture”, “Mechanical Loading”. Two reviewers performed screening and analyzed the data. Only the in vitro studies that reported on load-bearing capacity of only FDP materials where mean or median values reported in Newton (N) were included. **Results:** The selection process resulted in the 57 studies. In total, 36 articles were identified related to all-ceramics, 10 were fiber reinforced composite resin (FRC), 8 of composite resin (C) and 5 of metal-ceramic. As for clinical indications, 3 and 4-unit FDPs were more commonly studied (n=32; with PDL=21, without PDL=11), followed by single crowns (n=13; with PDL=3, without PDL=10), and inlay-retained and cantilever FDPs (n=12; with PDL=8, without PDL=4). **Conclusion:** An inclination for decreased static fracture strength could be observed with the simulation of PDL but due to insufficient data this could not be generalized for all materials used for FDPs.

KEYWORDS: Ceramics, Dental prosthesis, Periodontal ligament.

Influência de parâmetros de testes na capacidade de suporte de carga de materiais protéticos utilizados para prótese dentária fixa: uma revisão sistemática

RESUMO

Objetivo: O objetivo deste estudo foi revisar sistematicamente a literatura para avaliar os testes de força de fratura estática aplicados para próteses dentárias fixas (FDPs) e analisar o impacto da simulação do ligamento periodontal (PDL) na resistência à fratura. **Material e Métodos:** Artigos científicos originais publicados na base de dados MEDLINE (PubMed) entre 01/01/1981 e 10/06/2018 foram incluídos nesta revisão sistemática. Foram utilizados os seguintes termos MeSH, termos de pesquisa e suas combinações: “Dentistry”, “Fracture Strength”, “Fracture Resistance”, “Fixed Dental Prosthesis”, “Fixed Partial Denture”, “Mechanical Loading”. Dois revisores realizaram a triagem e analisaram os dados. Apenas os estudos *in vitro* que reportaram a capacidade de suporte de carga de FDP, com os valores das médias ou medianas relatados em Newton (N) foram incluídos. **Resultados:** O processo de seleção resultou em 57 estudos. No total, 36 artigos foram identificados relacionados à restaurações totalmente cerâmicas, 10 em resina composta reforçada com fibra (FRC), 8 em resina composta (C) e 5 em metalocerâmica. Quanto às indicações clínicas, os PDF de 3 e 4 unidades foram mais comumente estudados (n = 32; com PDL = 21, sem PDL = 11), seguidos de coroas isoladas (n = 13; com PDL = 3, sem PDL = 10) e FDPs retidas por inlays e com cantilever (n = 12; com PDL = 8, sem PDL = 4). **Conclusão:** Uma inclinação para a diminuição da resistência à fratura estática pôde ser observada com a simulação do PDL, mas devido a dados insuficientes, isso não pôde ser generalizado para todos os materiais utilizados para as FDPs.

PALAVRAS-CHAVE: Cerâmica, Prótese dentária, Ligamento periodontal.

1 INTRODUCTION

Durability of restorations is crucial for clinical dentistry since mechanical failures in the form of fractures have financial consequences both for the patient and the dentist. Removal and repair of restorations may be arduous and have also biological costs. Thus, decision for choosing the best performing material in terms of mechanical durability is often made based on the results of in vitro studies.

Load to fracture test is a common way of testing dental materials used for fixed dental prosthesis (FDP) to assess their mechanical strength for different indications. Today, an increased plethora of metal, all-ceramic or polymeric materials are being offered for clinical use. Neither ethically, nor technically it is possible to test their performance in randomized controlled clinical trials. Therefore, preclinical evaluations help to rank physical and mechanical properties of materials. Ranking prosthetic materials after such tests are generally taken into consideration for clinical indications especially for posterior segments of the mouth where increased chewing forces are experienced. Static load-bearing tests require a controlled environment where the specimen dimensions and the loading conditions are standardized. Besides recording fracture strength values, failure type and fractography analysis after such tests provide additional information on the origins and onset of the failure.

Although there are norms for testing FDP materials (DIN EN ISO 22674) [1], among in vitro tests, a great heterogeneity is being noticed in the dental literature related to load to fracture tests. While some studies were performed on metal abutments [2-9] others used polymers [16-22], or natural tooth [4,9,22] as abutment material. An important other factor is involvement of the periodontal ligament simulation (PDL) for tooth-borne FDPs. In an attempt to simulate the biological conditions and physiologic mobility of the teeth, different types of PDL materials are being used. The lack of PDL simulation could still contain useful information for

the durability of implant-borne FDPs. Yet, the consequence of using PDL in static loading tests is not known.

Since the test parameters vary considerably among the available published studies, there is apparent need to develop some guidelines in testing and interpreting the data on load-bearing capacity of different FDP materials in order to estimate their lifespan more realistically and not to deliver misleading information in terms of ranking materials for durability.

The objective of this systematic review was in particular to analyze the effect of PDL simulation on the load-bearing capacity of different FDP materials for different prosthetic indications.

2 MATERIAL AND METHODS

2.1 Search strategy

Before the initiation of the literature search, a protocol to be followed was agreed upon by the authors. An electronic search at MEDLINE (PubMed) (<http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>) from 01/01/1981 and 10/06/2018 was conducted for English-language articles published in the dental literature, using the following MeSH terms, search terms and their combinations: “Dentistry”, “Fracture Strength”, “Fracture Resistance”, “Fixed Dental Prosthesis”, “Fixed Partial Denture”, “Mechanical Loading”. The MEDLINE search are presented in Table I. In addition, hand searches were performed on bibliographies of the selected articles as well as identified narrative reviews to find out whether the search process has missed any relevant article. This did add the new four additional articles to be involved in the review process.

Table I: Search strategy in MEDLINE applied for this review. #: search, MeSH: Medical subjects heading, a thesaurus word.

| Search | Literature search strategy |
|-----------|---|
| <u>1</u> | <u>"Fracture Resistance and Fixed Partial Denture AND Dentistry"</u> |
| <u>2</u> | <u>"Fracture Resistance and Fixed Dental Prosthesis AND Dentistry"</u> |
| <u>3</u> | <u>"Fracture Strength AND Fixed Dental Prosthesis AND Dentistry"</u> |
| <u>4</u> | <u>Fracture Strength AND Fixed Partial Denture AND Dentistry"</u> |
| <u>5</u> | <u>"Mechanical Loading AND Fixed Dental Prosthesis AND Dentistry"</u> |
| <u>6</u> | <u>Mechanical Loading AND Fixed Partial Denture and Dentistry"</u> |
| <u>7</u> | <u>"Mechanical Loading AND Fracture Resistance and Fixed Dental Prosthesis"</u> |
| <u>8</u> | <u>"Mechanical Loading AND Fracture Resistance AND Fixed Partial Denture "</u> |
| <u>9</u> | <u>Mechanical Loading AND Fracture Strength AND Fixed Dental Prosthesis</u> |
| <u>10</u> | <u>Mechanical Loading AND Fracture Strength AND Fixed Partial Denture</u> |
| <u>11</u> | <u>Mechanical Loading AND Fracture Strength AND Fracture Resistance AND</u> <u>Dentistry</u> |

2.2 PICOs

The population, intervention, comparison and outcomes, i.e. the “PICOs” for this systematic review were defined as follows:

Population: Type of material (metal-ceramic - MC, all ceramic - AC, fibre-reinforced composite - FRC, composite resin – C. Type of restoration (FDPs of 3 units, 4 units, retained by inlay and cantilever);

Intervention: test method (static loading);

Comparison: with periodontal ligament and without periodontal ligament;

Outcomes: static fracture strength;

Study design: *in vitro* studies.

2.3 Inclusion/Exclusion criteria

In vitro studies reporting on load-bearing capacity of only FDP materials where mean or median values reported were included. Publications were excluded if fatigue loading was performed or data were not presented in Newton (N). Also, studies performed with finite element analysis were excluded.

2.4 Study selection

The search process led to titles of 1559 journal articles reviewed by two independent reviewers for possible inclusion in this systematic review. After title screening, 125 abstracts were considered relevant and full-text articles were downloaded. Thereafter, from 125 journal articles, 57 were included in this review. The process of identifying the studies included in the review is presented in Figure 1.

2.5 Data extraction

The two reviewer's extracted data independently using a data extraction form previously agreed upon. The process of identifying the studies included in this review is presented in Fig. 1. Data on the following parameters were extracted: author(s), year of publication, type of material tested, type of restoration, number of samples per group, periodontal ligament simulation material, substrate, fatigue conditions and fracture resistance in Newton. The data were presented according to the type of restoration: single crowns, 3-unit FDP, 4-unit FDP, inlay-retained and cantilever FDPs (tables II, III and IV). Disagreement regarding data extraction was resolved by discussion and a consensus was reached.

2.6 Risk of bias assessment

The risk-of-bias was assessed based on previous studies [23]. The risk of bias was calculated from 6 criteria: sample size calculation, sample randomization, sample preparation, specified aging, standardization of procedures by ISO and operator. For each parameter values from 0 to 2 were attributed: 0 – if the authors clearly reported the parameter; 1 – if the author reported the execution/respect of the parameter but accuracy of the execution is unclear; 2 – if the author did not specify the parameter or the information is not present. If the total sum of the attributed values ranged between 0 up to 4 it was considered a low risk, between 5 up to 9 a medium risk and 10 up to 14 a high risk of bias.

3. RESULTS

3.1 Characteristics of the included/excluded studies

Two independent reviewers screened the 1559 titles retrieved from the electronic search for possible inclusion in the review. After initial elimination, based on the titles and the abstracts, 744 abstracts were accepted for inclusion by both reviewers. The two reviewers independently

assessed the 125 full-text articles to determine whether they fulfilled the defined criteria for final inclusion. 72 articles had to be excluded after full text reading and risk of bias. Any disagreement was resolved by discussion. Finally, 57 studies were found to qualify for inclusion in the review. Among all studies included, all-ceramics (n=36) were more commonly tested followed by FRC (n=10), composite (n=8) and metal-ceramic (n=5). As for clinical indications, 3 and 4-unit FDPs were more commonly studied (n=32; with PDL=21, without PDL=11), followed by single crowns (n=13; with PDL=3, without PDL=10), and inlay-retained and cantilever FDPs (n=12; with PDL=8, without PDL=4). Tables II, III and IV [2, 3, 5, 7, 9, 17-21, 23-69]. According to the results, from 57 studies included, 32 involved PDL. In all selected subgroups, the search identified the use of wax, silicon, gummy resin, latex, vinyl silicone impression, acrylic resin base and silicone rubber to simulate PDL. The studies also used some kind of substrate, among them vital teeth such as third molars (n=21), pre molars (n=18) and central incisors (n=4); artificial teeth (n=8) or implants/metal (n=7) to simulate clinical conditions.

3.2. Risk of bias

According to the bias risk assessment, 57 studies included in this systematic review presented a medium risk of bias (between 5 and 9). The others articles presented a low risk of bias (between 0 and 4). The data were described in table V. Most of the studies did not describe the sample size calculation, the laboratory procedures by a single operator and standardization of procedures (ISO).

Table II: Characteristics from the studies included in the systematic review of single crowns.

| <u>Autor/Ano</u> | <u>Tipo de material</u> | <u>Number of specimens each group</u> | <u>Ligame nto perodo ntal/Mat erial</u> | <u>Fatigue conditions</u> | | | <u>Fracture strength (N)</u> |
|------------------------------------|---|---|---|-------------------------------|---|------------------------------------|--|
| | | | | <u>Aging</u> | <u>Number of cycles</u> | <u>Force/te mperatu re</u> | |
| <u>Dogan, et al., 2017</u> | <u>(FEL)/W(RNC) Lava ceramic(Vita Mark II, Lava Lithium disilicate glass (LD) IPS e.max CAD, feldspathic glass ceramic(FEL) Vita Mark II, and resin nano-ceramic (RNC) Lava Ultimate.</u> | <u>n=12</u> | <u>:</u> | <u>Titanium abutments</u> | <u>Thermocycling/ 6,000 thermocycles</u> | <u>5°C/55°C</u> | <u>(FEL) Vita Mark II (RNC) LD > FEL > RNC for F- initial load value and (LD > RNC) > FEL for F-max load value.</u> |
| <u>Hussien et al., 2016</u> | <u>Implant-supported crowns : monolithic zircônia (MZ), veneered zircônia(VZ), and lithium disilicate(LD)</u> | <u>n=10</u> | <u>:</u> | <u>:</u> | <u>:</u> | <u>:</u> | <u>MZ>LD>VZ. (p<0,05)</u> |
| <u>Weyhrauch, et al., 2016</u> | <u>(Vita Mark II, [FSC]; Empress CAD, [LrGC]; Ivoclar e.max CAD, [LiDS]; Vita Suprinity, [PSZirLS]; Vita Enamic, [PolyFSP]; Lava Ultimate; [ResNC]; Celtra Duo.</u> | <u>N=525</u> | | <u>implant abutments</u> | <u>37°C for 30 minutes/ 5,000 cycles of thermocycling</u> | <u>5°C/55°C</u> | <u>LiDS, PSZirLS, PolyFSP, and ResNC > that FSP, FcZirLS, and LrGC. The PSZirLS ceramic especially showed significantly better results. (p<0,05)</u> |

[FcZirLS]

| | | | | | | | |
|---------------------------------------|--|--|---|----------------------------------|---|----------------|--|
| <u>Altamimi et. al</u> <u>2014</u> | <u>Bilayered</u> <u>zirconia/fluorapatite</u> <u>and monolithic</u> <u>lithium disilicate</u> | <u>n = 10</u> <u>G1: bilayered zirconia/</u> <u>standard design crown</u> <u>copings . G2: bilayered</u> <u>zirconia/</u> <u>anatomical design crown</u> <u>copings.G3: lithium disilicate</u> <u>monolithic</u> <u>crowns</u> | : | <u>Metal</u> | | <u>250 N</u> | <u>G1 (561.87 ± 72.63) < G2</u> <u>(1,014.16 ± 70.18) < G3</u> <u>(1,360.63 ± 77.95)</u> |
| | | | | | <u>100,000</u> <u>masticatory</u> <u>cycles</u> | | |
| <u>Taguchi., 2014</u> | <u>Porcelain-fused-to-</u> <u>metal crowns (PFM),</u> <u>zirconia-based all-</u> <u>ceramic crowns</u> <u>(ZAC), zirconia-based</u> <u>indirect composite-</u> <u>layered (ZIC-E), and</u> <u>zirconia-based</u> <u>indirect composite-</u> <u>layered crowns (ZIC)</u> | <u>n=11</u> | : | : | <u>37°C for 24 h</u> | <u>=</u> | <u>:</u> <u>ZIC< PFM, ZAC, ZIC-E.</u> <u>(P < 0.044)</u> |
| <u>Nie et. al 2013</u> | <u>Cobalt–chromium</u> | <u>n = 22</u> <u>G1: mechanical loading</u> <u>G2: no pre-treatment</u> | : | <u>human</u> <u>premolars</u> | <u>37°C/ 3 days</u> | <u>127.4 N</u> | <u>G1 = G2</u> |
| | | | | | <u>1,200,000</u> <u>masticatory</u> <u>cycles</u> | | |

| | | | | | | | | |
|----------------------------------|---|---|---|-------------------------------------|---|---|---|---|
| <u>Abou-Madina, et al., 2012</u> | <u>Empress 2</u> | <u>n=16</u> <u>G1: Unprepared molars.</u> <u>G2: cemented with Panavia F 2.0.</u> <u>G3: cemented with Rely X Unicem</u> | <u>Yes/ silicone rubber (Imprint II, 3M ESPE)</u> | <u>human maxillary first molars</u> | <u>Thermocycling/s</u> <u>tored in distilled water</u> | <u>5,000 thermocycles</u> | <u>5°C/55°C</u> <u>60 seconds,</u> <u>transfer time: 12 seconds./ (37°C ± 1°C).</u> | <u>G1 (1,043)> G2 and G3. (P < .05). Cement type did not significantly affect fracture resistance (P > .05)</u> |
| <u>Attia et al 2006</u> | <u>Composite resin (CR) or lithium dissilicate (LD)</u> <u>Thermal cycling and mecânica lloading (TCM)</u> | <u>n = 8</u> <u>G1: CR, RelyX ARC, TCM</u> <u>G2: CR, RelyX ARC, no TCM. / G3: CR, GC Fuji CEM, with TCM. /G4: CR, GC Fuji CEM, no TCM./ G5: CR, zinc phosphate, with TCM./ G6: CR, zinc phosphate, no TCM./ G7:LD, RelyX ARC, TCM. G8: LD, RelyX ARC, no TCM. G9: LD, GC Fuji CEM, with TCM. G10: LD, GC Fuji CEM, no TCM G11: LD, zinc phosphate, with TCM. G12: LD, zinc phosphate, no TCM</u> | <u>Gum resin</u> | <u>human premolars</u> | <u>Storage in distilled: 1 week / 37°C</u> <u>600,000 masticatory cycles</u> <u>3500 thermal cycles</u> | <u>58°C - 4°C (for 60 seconds) / 49 N</u> | <u>G4 (914.7 ± 131.7) > G6 (827.1 ± 86.3) – p = 0.12</u> <u>G10 (923.6 ± 153.5)> G12 (772.3 ± 134.7) – p = 0.12</u> <u>G2 (955.9 ± 130.6) > G6 (827.1 ± 86.3) – p = 0.003</u> <u>G8 (929.1 ± 148.5) > G12 (772.3 ± 134.7) – p = 0.003</u> <u>G3 (706.2 ± 122.8) > G5 (552.5 ± 123.6) – p = 0.002</u> <u>G9 (721.1 ± 141.5) > G11 (571.5 ± 117.9) – p = 0.002</u> <u>G1 (724.4 ± 117.8) > G5 (552.5 ± 123.6) – p = 0.001</u> <u>G7 (752.7 ± 99.6) > G11 (571.5 ± 117.9) – p = 0.001</u> | |

| | | | | | | | |
|--|---|---|----------------------|---|---|---|---|
| <u>Mitov et. al 2005</u> | <u>Monolithic zirconia crowns</u> | <u>n = 10</u> <u>Groups: shoulderless preparation (SP)/ no pre-treatment X thermal cycling and mechanical loading.</u> | <u>:</u> | <u>Acrylic maxillary right molar</u> | <u>3 hours of autoclave treatment/ 134°C/ 2 bar</u> <u>1,200,000 masticatory cycles</u> <u>5,000 thermal cycles</u> | <u>5°C - 55°C / 50 N</u> | <u>Shoulderless preparation > chamfer preparation - p < 0.001</u> <u>No pre-treatment > artificial aging procedures - p < 0.001</u> |
| <u>Attia et al., 2004</u> | <u>All-ceramic crowns: lithium disilicate glass-ceramic (IPS-Empress 2) and a leucite-reinforced glass ceramic (ProCAD)</u> | <u>n=8</u> <u>IPS- Panavia F</u> <u>IPS Superbond</u> <u>ProCAD –Panavia F</u> <u>ProCAD- Superbond</u> | <u>Yes/gum resin</u> | <u>human premolars</u> | | <u>Under wet conditions for 600,000 masticatory cycles and 3500 thermal cycles between 4°C and 58°C (dwell time 60 seconds)</u> | <u>Cyclic loading did not significantly influence the median fracture load of the natural teeth (control) (P=.430), Empress 2 (P=.431) and ProCAD (P=.128) crowns luted using Panavia F.</u> |
| <u>Ku et al., 2002.</u> | <u>Metal-ceramic crowns and three ceromer crowns (Artglass, Sculpture, Targis).</u> | <u>N=40/n=10</u> | <u>No</u> | <u>Maxillary central incisor</u> | <u>No</u> | <u>:</u> | <u>:</u> <u>Metal-ceramic crowns (1317) > Artglass (575), Sculpture (621) and Targis (602). (p<0,05). Artglass (575)=Sculpture (621)= Targis (602) (P>0,05)</u> |
| <u>Rosentritt et al. 2000 *single crowns</u> | <u>All- ceramic (Empress 2, Ivoclar)</u> | <u>N=28</u> | <u>No</u> | <u>Artificial teeth (Vectra, Ivoclar)/ Metal Alloy Teeth (Co-Cr-Mo; Bioseal F, Kulzer)/</u> | <u>Thermocycling and mechanical loading</u> | <u>6,000 thermocycles</u> <u>-1.2 × 10⁶</u> | <u>5°C/55°C</u> <u>50N</u> <u>Fracture force was higher for crowns fixed on substitute materials (alloy = 1,838 N; LCP = 1,392 N) than for crowns on human teeth (888 N). (p<0,05)</u> |

Human molars

| | | | | | | | |
|---------------------------------------|--------------------------|-------------------------------------|-----------|--------------------------|---------------|------------------|---------------------------------|
| <u>Scherrer et al.</u> <u>1996</u> | <u>Oxide all-ceramic</u> | <u>N=40</u> | <u>No</u> | <u>Storage</u> <u>in</u> | <u>5 days</u> | <u>room</u> | <u>G1(1.28 kN) =G2(1.56</u> |
| | | <u>G1: feldspathic</u> | | <u>distilled</u> | | <u>temperatu</u> | <u>kN)=G3(2.06kN). (p=n.a)</u> |
| | | <u>Porcelain; G2: castable</u> | | <u>water.</u> | | <u>re</u> | |
| | | <u>glass-ceramic.; G3: glass-</u> | | | | | |
| | | <u>infiltrated alumina ceramic.</u> | | | | | |

Table III: Characteristics from the studies included in the systematic review of Fixed Dental Prosthesis 3-unit and 4-unit.

| <u>Autor/Ano</u> | <u>Tipo de material</u> | <u>Type of restoration</u> | <u>Number of specimens each group</u> | <u>Ligamento periodontal/ material</u> | <u>Substrato</u> | <u>Fatigue conditions</u> | | | <u>Fracture strength (N)</u> |
|-----------------------|---|---|--|--|----------------------------------|--|-------------------------|--------------------------|------------------------------|
| | | | | | | <u>Aging</u> | <u>Number of cycles</u> | <u>Force/temperature</u> | |
| Partiyan et al., 2017 | Zirconia: manually aided design—manually aided milling (MAD/MAM) and Computer assisted design—computer assisted milling (CAD/CAM) | Three-unit zirconia fixed partial denture | n=20 Group I (MAD/MAM) conventional. Group II: (MAD/MAM) Innovative. Group III (CAD/CAM). Conventional Group IV (CAD/CAM). Innovative. | Yes/acrylic resin base | second premolar and second molar | Stored in distilled water/ thermocycling | 72hrs/1000 cycles | 37°C/5°/55°C. 30s. | G2>G4>G3>G1 (P<0.0001). |
| Murase et al., 2014 | 5% Y-TZP (Aadva Zirconia, GC) | All-ceramic fixed partial dentures (FPDs) | n=15 cross-sectional áreas: 1: 9.0mm ² 2: 7.0 mm ² 3: 5.0 mm ² | Yes/vinyl silicone impression | Central and lateral incisors | stored in distilled water | 24hrs | 37°C | 1> 2 > 3. (p<0.001) |

| | | | | | | | | | |
|---------------------------------|--|--|--|----------------------|---|---|---|---|--|
| <u>Chaar, et al., 2013</u> | <u>LV (layering technique/Vintage ZR); LZ (layering technique/ZIROX); PP (CAD/CAM and press-over techniques/PressXZr</u> | <u>3-unit posterior fixed dental prostheses (FDPs)</u> | <u>n=16</u> <u>G1: LV G2: LZ G3: PP</u> | <u>Yes/gum resin</u> | <u>Human premolars</u> | <u>thermo-mechanica</u> | <u>1 200 000 cycles</u> | <u>=</u> | <u>G2> G1>G3. (NON-AGED)</u> <u>G3>G2>G1 (AGED)</u> <u>(P<0.05)</u> |
| <u>Eroglu and Gurbulak 2013</u> | <u>zirconia-ceramic (ZC), galvano-ceramic (GC), and porcelain-fused-to-metal (PFM)</u> | <u>Fixed partial denture 3- unit</u> | <u>n = 10</u> <u>ZC, GC and PFM with or without thermocycling and mechanical loading (TCM)</u> | <u>No</u> | <u>Metal (maxillary canine and second premolar)</u> | <u>Thermocycling and mechanical loading</u> | <u>- Thermocycling: 10,000 cycles</u> <u>- Mechanical loading: 100,000 cycles.</u> | <u>Thermocycling: 5° - 55°;</u> <u>Mechanical loading: 50 N;</u> | <u>GC (1678.1 ± 211.6) > GC/TCM (1475.8 ± 227.9) - p < 0.05</u> <u>PFM (1878.5 ± 176.5) > PFM/TCM (1687.8 ± 162.2) - p < 0.05</u> |
| <u>Takuma, Y. et al., 2013</u> | <u>3% Y-TZP (Everest® Zirconium Soft)</u> | <u>4-unit all-ceramic FPDs</u> | <u>Framework connectors cross-sectional áreas: A:9.0 or B: 7.0mm²).</u> <u>Cross-sectional forms:</u> <u>a circular form (1:1 (Type A); an oval form, (3:4 (type B); and another oval (2:3 (type C).</u> <u>Connector types:</u> <u>mesial/distal connectors (A-A,</u> <u>B-B, C-C) and central connector (-A-, -B-, -C-).</u> | <u>=</u> | <u>=</u> | <u>stored in distilled water</u> | <u>24hrs</u> | <u>37°C</u> | <u>Cross-sectional área: A>B. (p<0,01)</u> <u>Mesial and distal connector's type: A-A> C-C. (p<0,01)</u> <u>Central connector's type: A>C (p<0,05); A>B (p<0,01)</u> |

| | | | | | | | | | |
|--------------------------------|---|---|--|-----------------------|--|---|---------------------------------------|---|---|
| <u>Preis et al., 2012.</u> | <u>Yttria-stabilized zirconia (Cercon ht, Degudent)</u> | <u>Three-unit zirconia-based FPDs</u> | <u>n=8</u> <u>G1: AD – sintered; G2: AD – sintered – glazed; G3: AD – sintered – sandblasted – glazed; G4: AD – sintered – polished – grinded (contact points adjusted); G5: AD – sintered – polished – grinded – repolished; G6: ARD – sintered – veneered; G7: control: analogous to #3 but without thermal cycling (TC) and mechanical loading (ML).</u> | <u>Yes/wax</u> | <u>Artificial identical polymethyl methacrylat (PMMA) molars</u> | <u>thermal cycling and mechanical loading (</u> | <u>TC: 6000</u> | <u>5°/55° × 2 min each cycle</u> <u>1.2 × 10⁶ × 50 N; 1.6 Hz)</u> | <u>No statistically significant differences were found between the groups (p = 0.910)</u> |
| <u>Salimi, H. et al., 2012</u> | <u>Cercon Base ceramic, Degudent, Germany</u> | <u>Zirconium oxide posterior fixed partial dentures (FPD)</u> | <u>Group I: copings with 3 × 3 connector dimension and standard design</u> <u>Group II: copings with 3 × 3 connector dimension and modified design</u> <u>Group III: copings with 4 × 4 connector dimension and standard design</u> <u>Group IV: copings with 4 × 4 connector dimension and modified design.</u> | <u>=</u> | <u>Maxillary typodont model</u> | <u>artificial saliva at 37°C/ thermocycling</u> | <u>2000 cycles</u> | <u>5 and 55°C for 30 s each, with an intermediate pause of 15 s.</u> | <u>Group IV was significantly higher than group I (P < 0.001) and group II (P < 0.001), but there was not any significant difference between group IV and group III (P = 0.156)</u> |
| <u>Nothdurft et al 2011</u> | <u>zirconia</u> | <u>Fixed partial denture 3- unit</u> | <u>n = 8</u> <u>Implant -</u> <u>tooth supported</u> <u>restorations (IT)</u> | <u>Yes/ Gum resin</u> | <u>Zirconia abutments and cast metal teeth (First molar and pre-molar)</u> | <u>Thermocycling</u> | <u>- Thermocycling: 10.000 cycles</u> | <u>Thermocycling: 5° - 55°:</u> | <u>IT < II- p < 0.05</u> <u>iTC < nTC- p < 0.05</u> |

or

implant -implant (II)with:

- individualised
abutments (i) or no
individualised (ni)

- with (TC) or without
thermocycling (N)

| | | | | | | | | | |
|------------------------------------|--|---|--|------------------------------|---|---|-------------------------|--|---|
| <u>Onodera et al., 2011.</u> | <u>3 vol% (YTZP: Kavo Everest® Zirconium Soft, Biberach, Germany)</u> | <u>all-ceramic FPDs molar region</u> | <u>n=15.</u> <u>Cross-sectional area: A: 9.0, B: 7.0; C:5.0mm.</u> <u>Conector shape: A: 1:1, B: 3:4, C: 2:3</u> | <u>Yes/Silicone material</u> | <u>Second premolar and second molar</u> | <u>stored in distilled water</u> | <u>24hrs</u> | <u>37°C</u> | <u>Cross-sectional area (mm2): A>B>C. P<0.05).</u> <u>Conector shape: A=B=C. (p<0.05)</u> |
| <u>Rosentritt, M. et al., 2011</u> | <u>Glass-infiltrated, alumina based, all-ceramic material (Inceram Alumina, Vita Zahnfabrik)</u> | <u>All-ceramic three-unit fixed partial dentures (FPDs)</u> | <u>n=8</u> <u>Group A (control):</u> <u>in polymethyl methacrylate (PMMA).</u> <u>Group B: polyether layer (Impregum, 3M ESPE). Group C: polyether layer during aged.</u> | <u>Yes/ wax bath</u> | <u>human molars</u> | <u>Thermal cycling and mechanical loading</u> | <u>TC: 6000 cycles.</u> | <u>5°/55° × 2 min each cycle:</u> <u>1.2 × 10⁶ × 50 N: 1.6 Hz)</u> | <u>Group A> Group C (P = .047)= B (P = .364).</u> <u>Goup C=B. (P = .961)</u> |
| <u>Eisenburger et. al. 2008</u> | <u>Composite resin. (Protemp, Luxatemp, Cron-Mix).</u> <u>different without two</u> <u>translucent-fibre</u> <u>different without two</u> <u>translucent-fibre</u> <u>different without two</u> <u>translucent-fibre</u> <u>different</u> <u>translucent-fibre</u> | <u>Fixed partial denture 4- unit</u> | <u>30</u> | <u>Yes/ Latex varnish</u> | <u>Artificial resin teeth (24 and 27)</u> | <u>Thermocycling</u> | <u>10.000</u> | <u>5 – 55 °C</u> | <u>Luxatemp > CronMix (p=0.014)</u> <u>Luxatemp - Without fibre Stick > EverStick (p= 0.004)</u> |

With and without two
glass- fibre
reinforcement

CronMix: Without
fibre > EverStick (p
= 0.015)

| | | | | | | | | | |
|--------------------------------|---|--|--|---------------------------|--|-------------------------------------|---------------------------|---|---|
| <u>Att et al. 2007</u> | <u>Zirconia (DCS, Procera and Vita CerecInlab)</u> | <u>Fixed partial denture 3- unit</u> | <u>n= 8</u> <u>G1: DCS with artificial aging;</u> <u>G2: DCS without artificial aging;</u> <u>G3: Procera with artificial aging;</u> <u>G4: Procera without artificial aging;</u> <u>G5: Vita with artificial aging;</u> <u>G6: Vita without artificial aging.</u> | <u>Yes/ Gum resin</u> | <u>Human mandibular premolars and molars</u> | <u>Termomechanica I fatigue</u> | <u>- 1.200.000 cycles</u> | <u>- Mechanical loading: 49 N;</u> <u>- Thermocycling: 5° - 55°.</u> | <u>G3 (1297) < G5 (1593) – p= 0.015</u> <u>G3 < G1 (1618) – p= 0.038</u> |
| <u>Att et al. 2007* Zr</u> | <u>Zirconia (DCS, Procera and Vita CerecInlab) veneered using Vita VM9.</u> | <u>Fixed partial denture 3- unit</u> | <u>n= 8</u> <u>G1: DCS with artificial aging; G2: DCS without artificial aging; G3: Procera with artificial aging; G4: Procera without artificial aging;</u> <u>G5: Vita with artificial aging;</u> <u>G6: Vita without artificial aging.</u> | <u>Yes/ Gum resin</u> | <u>Human mandibular premolars and molars</u> | <u>Termomechanica I fatigue</u> | <u>- 1.200.000 cycles</u> | <u>- Mechanical loading: 49 N;</u> <u>- Thermocycling: 5° - 55°.</u> | <u>G3 (1094) < G1 (1481) – p= 0.042</u> |

| | | | | | | | | | |
|-----------------------------|--|--------------------------------------|---|-------------------|--|--|---|--|--|
| <u>Larsson et al. 2007</u> | <u>Zirconia (Procera)</u> | <u>Fixed partial denture 4- unit</u> | 8 <u>G1: 2.0 mm connector:/</u> <u>G2: 2.5 mm conector:/</u> <u>G3: 3.0 mm conector:/</u> <u>G4: 3.5 mm conector:/</u> <u>G5: 4.0 mm conector.</u> | No | <u>Artificial acrylic resin teeth (34 and 37)</u> | <u>Thermocycling and mechanical loading.</u> | <u>- Mechanical loading: 10 000:</u> <u>- Thermocycling: 5000.</u> | <u>- Mechanical loading: 30 -300 N;</u> <u>- Thermocycling: 5° - 55°.</u> | <u>G1 and G2 fractured during preload (30–300 N, 10 000 cycles);</u> <u>G5 (897) > G4 (602) > G3 (428).</u> |
| <u>Kohorst et al. 2007</u> | <u>Zirconia – Partially sintered (Cercon); Fully sintered zirconia (Digizon)</u> | <u>Fixed partial denture 4- unit</u> | 10 <u>G1: Cercon without preliminar echanical damage; G2: Cercon with preliminar mechanical damage;</u> <u>G3: Digizon without preliminar mechanical damage;</u> <u>G4: Digizon with preliminar mechanical damage.</u> | <u>Yes/ Latex</u> | <u>Artificial polyurethane resin teeth (24 and 27)</u> | <u>Storage, thermocycling and mechanical loading</u> | <u>- Storage: distilled water at 36 °C for 200 days;</u> <u>- Thermocycling: 10⁴ cycles</u> <u>- Mechanical loading: 10⁶ cucle.</u> | <u>- Thermocycling: 5° - 55°;</u> <u>-Mechanical loading: 100 N;</u> | <u>G1 (903.7) < G3 (1262.6);</u> <u>G2 (921.1) < G4 (1132.4).</u> |
| <u>Pfeiffer et al. 2006</u> | <u>Thermoplastic polymer (Promysan Star), veneering composite (Vita Zeta or Sinfony), non-impregnated (Ribbond) and impregnated polyethylene fiber reinforced resin (Targis/Vectris);C onventional poly methyl</u> | <u>Fixed partial denture 4- unit</u> | n= 3 <u>G1: Biodent – 4.3 pontic height;</u> <u>G2: Biodent – 5.8 pontic height;</u> <u>G3: Promysan - 4.3 pontic height;</u> <u>G4: Promysan - 5.8 pontic height;</u> | No | <u>CoCr-alloy (premolar maxillary and molar)</u> | <u>Thermocycling</u> | <u>5.000</u> | <u>5 – 55 °C</u> | <u>- G9 and G10 (197.4 – 377.0) > others groups (p < 0.05);</u> <u>- G6 (97.2) < G1, G2,G3, G4, G7, G8 (p < 0.05);</u> <u>- G1 (197.4) < G2 (377.0) - p < 0.05).</u> |

| | | | | | | | | | |
|--|--|--|--|---------------------------------|--|---|---------------------------|--|---|
| | <u>methacrylate</u> <u>(Biodent K+B).</u> | | <u>G5: Promysan/Vita Zeta</u> <u>- 4.3 pontic height;</u> | | | | | | |
| | | | <u>G6: Promysan/Vita Zeta</u> <u>- 5.8 pontic height;</u> | | | | | | |
| | | | <u>G7: Ribbond/Sinfony -</u> <u>4.3 pontic height;</u> | | | | | | |
| | | | <u>G8: Ribbond/Sinfony -</u> <u>5.8 pontic height;</u> | | | | | | |
| | | | <u>G9: Vectris/Targis - 4.3</u> <u>pontic height</u> | | | | | | |
| | | | <u>G10: Vectris/Targis -</u> <u>5.8 pontic height</u> | | | | | | |
| <u>Rosentritt et</u> <u>al. 2006</u> | <u>Lithium disilicate</u> <u>(Empress 2)</u> | <u>Fixed partial</u> <u>denture 3- unit</u> | <u>n= 8</u> | <u>Yes/</u> <u>Polyether</u> | <u>Human</u> <u>molar or</u> <u>CoCr-alloy</u> <u>or Liquid</u> <u>Crystal</u> <u>Polymer</u> | <u>Termomechanica</u> <u>I fatigue</u> | <u>- 1.200.000 cycles</u> | <u>- Mechanical</u> <u>loading: 50 or</u> <u>150 or 50-100-</u> <u>150 N;</u> | <u>Human abutments</u> <u>and artificial</u> <u>periodontium (410)</u> <u>< human</u> <u>abutments and no</u> <u>artificial</u> <u>periodontium (783)</u> |
| | | | | | | | | <u>- Thermocycling:</u> <u>25° or 5° - 55°.</u> | |
| <u>Stiesch-</u> <u>Scholz et al.</u> <u>2006</u> | <u>Fiber-reinforced</u> <u>(EverStick or</u> <u>Vectris).</u> <u>composite resin</u> <u>(Sinfony or Vita</u> <u>Zeta or Targis)</u> | <u>Fixed partial</u> <u>denture 4- unit</u> | <u>n= 10</u> | <u>Yes/ Latex</u> | <u>Polyuretha</u> <u>ne-based</u> <u>resin (24</u> <u>and 27</u> <u>teeth)</u> | <u>Thermocycling</u> | <u>10.000</u> | <u>5 – 55 °C</u> | <u>G2, G4, G6, G7</u> <u>(615 – 1191) > G1,</u> <u>G3, G5 (178 – 307)</u> <u>– p< 0.05;</u> <u>G2 (1137) > G4</u> <u>(878), G6 (615) -</u> <u>p< 0.05;</u> <u>G1 (307), G5 (276)</u> <u>> G3 (178) – p<</u> <u>0.05;</u> |
| | | | <u>G1: Sinfony; G2:</u> <u>Sinfony/ EverStick; G3:</u> <u>Vita Zeta. G4: Vita Zeta/</u> <u>EverStick ;</u> <u>G5: Targis; G6: Targis/</u> <u>EverStick G7: Targis/</u> <u>Vectris.</u> | | | | | | |

| | | | | | | | | | |
|---|--|--------------------------------------|--|-----------------------|---|---|---|---|---|
| <u>G6 (615) < G7 (1191) – p< 0.05.</u> | | | | | | | | | |
| <u>Rosentritt et al. 2005</u> | <u>metal-based FPDs (gold) with composite resin veneering</u> <u>with metal-based FPDs veneering</u> <u>with composite</u> | <u>Fixed partial denture 3- unit</u> | <u>n= 4</u> <u>G1: Adoro LC. G2: Adoro HP. G3: Adoro Thermo Graud. G4: Belleglass. G5: Sinfony</u> | <u>Yes/ polyether</u> | <u>Human molars</u> | <u>Thermocycling and mechanical loading</u> | <u>- Thermocycling: 6000 cycles</u> <u>- Mechanical loading: 10⁶ cycles.</u> | <u>- Thermocycling: 5° - 55°:</u> <u>-Mechanical loading: 100 N;</u> | <u>G1 (1555) > G5 (909) – p = 0.005</u> <u>G4 (1051) > G5 (909) – p = 0.0029</u> <u>G3 (1700) > G5 (909) – p = 0.007</u> |
| <u>G2 (2251 ± 120) > G3 (1611 ± 463) – p < 0.05</u> <u>G1 (3291 ± 444) and G2 (3480 ± 139) > the others groups – p< 0.05</u> | | | | | | | | | |
| <u>Sundh et al 2005</u> | <u>Yttria-stabilized zirconia</u> | <u>Fixed partial denture 3- unit</u> | <u>n= 5</u> <u>G1: delivered after machining, G2: delivered after machining, no dynamic loading in water. G3: heat-treatment similar to veneering (HT) with a glass–ceramic (Eris) G4: HT with feldspar-based</u> | <u>No</u> | <u>Stainless steel</u> <u>(second lower molar - second lower premolar)</u> | <u>Storage and mechanical loading</u> | <u>- Storage: distilled water at 37 °C for 24 h;</u> <u>- Mechanical loading: 10⁵ cycles.</u> | <u>-Mechanical loading: 50 N;</u> | <u>G2 (2251 ± 120) > G3 (1611 ± 463) – p < 0.05</u> <u>G1 (3291 ± 444) and G2 (3480 ± 139) > the others groups – p< 0.05</u> |

ceramic (Vita D) G5:
veneered (V) with ERis.
G5: V with Vita D

| | | | | | | | | | |
|--------------------------------------|--|--------------------------------------|--|----------------------|--|----------------------------------|-----------------------------|--|--|
| <u>Pfeiffer, et al., 2003.</u> | <u>Prosthetic resin materials</u> | <u>Fixed partial dentures (FPDs)</u> | <u>n=3</u> <u>G1: PMMA material.</u> <u>G2: Promysan Star</u> <u>G3: Promysan Star/Vita Zeta</u> <u>G4: Ribbond/Sinfony</u> <u>G5: Vectris/Targis</u> | <u>Yes/Wax</u> | <u>:</u> | <u>Storage and thermocycling</u> | <u>24 hours/5000 cycles</u> | <u>at room temperature (21°C)/</u> <u>5°/55°C, 30s.</u> | <u>G1=G2(p<0,05).</u> <u>G3<G4 and G5 (p<0,05)</u> |
| <u>Chitmongkol suk et al., 2002.</u> | <u>All Ceramic(AL) and Porcelain- fused to metal (PMF)</u> | <u>FDP 3 - unit</u> | <u>N=48/n=16</u> <u>G1: AL Normal Preparation.</u> <u>G2: AL Modified preparation.</u> <u>G3: PMF - Control</u> | <u>Yes/gum resin</u> | <u>Human mandibular premolars and molars</u> | <u>—</u> <u>:</u> | <u>:</u> | <u>:</u> | <u>PMF>G1>G2. (p<0,05)</u> |
| <u>Kolbeck et al., 2002* FDP</u> | <u>TM.</u> <u>/</u> <u>belleGlass HP.</u> <u>, 16 of the FibreKor</u> <u>TM.</u> <u>/Conquest</u> <u>TM.</u> <u>Sculp-</u> <u>ture</u> <u>TM.</u> <u>-system</u> | <u>FDP 3- unit</u> | <u>N=64</u> | <u>Yes/impregn</u> | <u>Human third molars</u> | <u>:</u> | <u>:</u> | <u>:</u> | <u>PFRF-FPDs (830 N) = GFRC-FPDs (884 N) (p =0.60)</u> |

| | | | | | | | | | |
|-----------------------------------|--|--|--|------------------|---------------------------------|--|----------------|----------------|---|
| | <u>Polyethylene-Fibre-reinforced-composite system (PFRC)</u> <u>glass-Fibre-reinforced-composite system (GFRC).</u> | | | | | | | | |
| <u>Nakamura et al., 2002</u> | <u>Glass-ceramic</u> | <u>FPD- 3 unit</u> | <u>N=5</u> <u>ithium disilicate core</u> <u>Corelita/Empress2*</u> <u>(Empress2 Porcelain).</u> <u>(Empress2 Porcelain)</u> <u>(Empress2 Porcelain)</u> <u>±</u> <u>)</u> <u>G1: Lithium disilicate</u> <u>(Empress2* Core), G2:</u> <u>layering dentin porcelain</u> <u>(Empress2 Porcelain),</u> <u>G3:leucite-based glass-</u> <u>ceramics(Empress*),</u> <u>G4: castable glass-</u> <u>ceramics (Dicort).</u> | <u>No</u> | <u>:</u> | <u>Storage</u> | <u>24hours</u> | <u>At room</u> | <u>G1>G3>G4.</u> <u>(p<0,01)</u> |
| <u>Ellakwa et al. 2001</u> | <u>Fibre-reinforced composite (Connect and Herculite XRV(Dentine).</u> | <u>FDP 3-unit</u> | <u>n=10</u> <u>G1: Connect/Wet.</u> <u>G2: Connect/Dry. G3:</u> <u>Herculite/Wet.</u> <u>G4: Herculite/Dry</u> <u>G5: Control/Wet.</u> <u>G6: Control/Dry.</u> | <u>No</u> | <u>No</u> | <u>the Connect fibre and Herculite XRV improved the flexural properties (p<0.05).</u> <u>Wet =Dry. (P>0.05)</u> | <u>:</u> | <u>:</u> | |
| <u>Kheradmand an et al., 2001</u> | <u>GC: AGC galvano-ceramic.</u> <u>CA:Celay In-Ceram Alumin. (E2): IPS Empress 2. CM) ceramo-metal (control).</u> | <u>FDP 3-unit</u> <u>GC: AGC galvano-ceramic.</u> <u>CA:Celay In-Ceram Alumin.</u> | <u>N=64/n=8</u> | <u>Gum resin</u> | <u>Human maxillary incisors</u> | <u>:</u> | <u>:</u> | <u>:</u> | <u>CM (681N)> GC (397N)>CA(239N);(p=0,085). E2 (292N)= CA (p=0,17) and GC. (p=0,14)</u> |

| | | | | | | | | | |
|-----------------------------|---|--|--|-------------------|---------------------------|-----------------------------|----------------|---------------------------------|---|
| (E2): IPS Empress 2 | | | | | | | | | |
| CM) ceramo-metal (control). | | | | | | | | | |
| El-Mowafy et al. 2000. | Nonprecious metal alloy (Litecast B, Ivoclar/Williams) | Modified resin-bonded fixed partial denture (RBFPD) - Cement-It. - Panavia 21 | N=70/n=7 G1: conventional RBFPDs- Cement it. G2 and G3: modified RBFPDs with retentive-slot Cement-It G4: RBFPDs with retentive-slot- Panavia 21. G5: similarly to the groups 2 and 3 but with inlay preparations instead of the retentive slots- Cement-It. | No | Premolar and Molar | Load cycling | 230,000 cycles | 4 Hz under water. | G2 (525 N) and G3(562 N)> G5(417 N> G1(361 N). (P = 0.0022) |
| Koutayas, et al., 2000 | Aluminum-oxide ceramic (In-Ceram, Vita, Bad Sackingen, Germany) | All-ceramic, resin-bonded fixed partial dentures (RBFPDs) – 3 unit. W1- cantilevered single-retainer Design. W2: conventional 2-retainer Design. | N=48/n=8 G1: W1/45 degree long axis angle. G2: W1/0 degree. G3: W2/45 degree G4: W2/0 degree | Yes/ gum resin | Maxillary central incisor | Dynamic load/ Thermocycling | n.a | 50 or 25 N at 1.3 Hz/5'-55' °C. | 45-degree loading, were between 134 and 174 N and under 0-degree loading about 233 N. (p>0.05) |

| | | | | | | | | | |
|-------------------------------|--|--|---|-----------------------|---------------------------|--|---|------------------------------|--|
| <u>Nohrström et al. 2000</u> | <u>Resin reinforced fiber</u> | <u>Fixed partial dentures (FPD) 3 and 4 – unit</u> | <u>N=5</u> <u>FPD unreinforced</u> <u>FPD reinforced</u> | <u>n.a</u> | <u>No</u> | <u>Storage</u> | <u>30 days.</u> | <u>Water at 37 for ± 1°C</u> | <u>The load fracture the unreinforced FPDs (372 to 1061 N) < that mean fracture load of reinforced FPDs (508 to 1297 N). (P < 0.001.</u> |
| <u>Rosentritt et al. 2000</u> | <u>All ceramic (classical IPS Empress, layering technique, Ivoclar).</u> | <u>Fixed partial dentures (FPD)</u> | <u>N=8</u> <u>3- unit</u> <u>4 -unit</u> | <u>Yes/ Impregum.</u> | <u>Human third molars</u> | <u>Thermal cycling and mechanical loading (TCML)</u> | <u>-6000 thermal cycles).</u> <u>-1.2 × 10⁶ mastication cycles</u> | <u>5°C/55° C/ 50 N, 8,3d</u> | <u>After TCML, the 4-unit FPDs > 3- unit FPDs. (p=0.455)</u> |
| <u>Vallittu et al. 1998</u> | <u>Resin</u> | <u>Fixed partial dentures (FPD)</u> | <u>n=5</u> <u>G1: No reinforcements (Control)</u> <u>G2:FPD 1R/</u> <u>G3:FPD:2R/</u> <u>G4:FPD:3R/</u> <u>(unidirectional glass fiber reinforcements (R)</u> <u>G5: FDP3R+1W (glass fiber weave reinforcement)</u> | <u>No</u> | <u>=</u> | <u>Storage in distilled water</u> | <u>10 days</u> | <u>37° ± 1°C</u> | <u>Control< 2R (p = 0.002) < 3R</u> <u>(p = 0.003)< 3R+1W (p < 0.001); 1R< 2R</u> <u>(p = 0.010); 1R< 3R (p = 0.013); 1R< 3R+1W (p = 0.001); 2R<3R+1W (p = 0.025); and 3R< 3R+1W (p = 0.044).</u> |
| <u>Kern et al. 1994</u> | <u>Oxide all-ceramic</u> | <u>Fixed partial dentures 3-unit.</u> | <u>n=10</u> <u>Design A: In-Ceram pontic was veneered on the labial aspect only.</u> <u>Design B: In-Ceram pontic framework was shifted to the labial</u> | <u>Yes/ gum resin</u> | <u>=</u> | <u>Storage and thermocycling</u> | <u>Storage 7 days: in 0.1 thymol solution at 37' C.</u> <u>Storage: 150 days in av</u> | <u>5'-55' °C.</u> | <u>Design A 7 days: 214.5N > design A 150days:171.6N < design B 7 days: 388.9N < design B: 150days: 296.0N. (p < 0.01).</u> |

aspect and veneered
circumferentially

tificial saliva at 37'
C and 18,750
thermal cycles.

Table IV: Characteristics from the studies included in the systematic review of inlay-retained and cantilever FDPs.

| <u>Autor/Ano</u> | <u>Tipo de restoration</u> | <u>Type of material</u> | <u>Number of specimens each group</u> | <u>Ligamento periodonta I</u> | <u>Substrato</u> | <u>Fatigue conditions</u> | | | <u>Fracture strength (N)</u> |
|----------------------------|---|---|--|---|--|-----------------------------------|--|--------------------------|---|
| | | | | | | <u>Aging</u> | <u>Number of cycles</u> | <u>Force/temperature</u> | |
| <u>Özcan et al., 2012</u> | <u>Inlay-retained FRC FPDs</u> | <u>Resin composite /natural tooth/acrylic denture/ porcelain denture tooth/resin composite.</u> | <u>n=9</u> <u>Material Type: a) resin composite; b) natural tooth, c) acrylic denture tooth, d) porcelain denture tooth and e) resin composite;Occlusal morphology: i) 'circular; ii) 'elliptic I';; iii) 'elliptic II'</u> | <u>Yes/Silicon</u> | <u>Premolar and molar</u> | <u>=</u> | <u>=</u> | <u>=</u> | <u>Group e (1,186 N) > a, b,c,d. (p<0,05). Groups a=b=c=d (p>0,05). Group iii (871 N) < ii and i. (p<0,05)</u> |
| <u>Mohsen et al., 2010</u> | <u>Ceramic inlay-retained fixed partial dentures</u> | <u>Zircon milled ceramic material.</u> | <u>n=10</u> <u>G1: inlay-shaped (occluso-proximal inlay + proximal box). G2: tub-shaped (occluso-proximal inlay). G3: proximal box-shaped preparations.</u> | <u>Yes/ epoxy resin</u> | <u>artificial teeth</u> | <u>stored and thermocycling (</u> | <u>24 hours/6000 cycles.</u> | <u>37 °C (5–55 °C)</u> | <u>G1>G2>G3 (p<0,05)</u> |
| <u>Xie et al. 2007</u> | <u>Fiber-reinforced composite (FRC)/ fixed partial dentures (FPDs) 3-unit</u> | <u>Composite resin</u> | <u>n = 6</u> <u>G1: unidirectional glass fiber;</u> | <u>Yes/ Polyether impression material</u> | <u>Human mandibular premolars and first molars</u> | <u>Storage and thermocycling</u> | <u>- Storage: distilled water at 37 °C for 24 h</u> <u>= Thermocyclin</u> | <u>5–55 °C</u> | <u>G4 (2353.8) > G1 (1497.8) - p = 0.000;</u> <u>G4 > G2 (1563.0) – p = 0.000;</u> |

| | | | | | | | | | |
|----------------------------|---|---|---|-----------|---|---|--|--|---|
| | | | <u>G2: unidirectional glass fiber with multidirectional fiber in pontic portion;</u> <u>G3: unidirectional glass fiber with short unidirectional fiber pieces in pontic portion;</u> <u>G4: unidirectional glass fiber with short unidirectional fiber pieces in pontic portion in 90° angle to the main framework.</u> | | | | <u>g: 6000× cycles</u> | | <u>G4 > G3 (1711.2) – p = 0.005.</u> <u>- Buccal cusp:</u> <u>G4 (1416.3) > G1 (1205.8) - p = 0.044:</u> <u>G4 = G2 (1106.7) – p = 0.065:</u> <u>G4 > G3 (1075.2) – p = 0.010.</u> <u>- Occlusal</u> <u>Fossa > Buccal cusp – for all groups (p < 0.05).</u> |
| <u>Dyer et al. 2005</u> | <u>Fixed partial denture 3-unit</u> | <u>Reinforced composite resin with glassfibers</u> | <u>n = 5</u> <u>G1: Crown preparation</u> <u>G2: Slot preparation</u> <u>G3: No tooth preparation</u> <u>G4: Combination design with a slot preparation and the thin, broad surface</u> | <u>no</u> | <u>Maxillary human molars</u> | <u>Storage and thermocycling</u> | <u>- Storage: distilled water at 37 °C for 1 week;</u> <u>= Thermocyclin g: 5000 cycles</u> | <u>= Thermocycli ng: 5° - 55°</u> | <u>- Initial failures:</u> <u>G2 (1284) < G4, G1 p<0.5</u> <u>- Final failures:</u> <u>G2 (1313) < G1 (1755), G3 (1758), G4 (1836) – p<0.5</u> |
| <u>Ohlmann et al. 2005</u> | <u>Fixed partial denture 3-unit or 4 - unit</u> | <u>Zircon frames veneered with the polymer glass (G) or zircon frames veneered with a press ceramic (C)</u> | <u>n= 8</u> <u>Proximal box (P)</u> <u>Occlusal box (O)</u> | <u>no</u> | <u>Cobalt–chromium alloy (second premolar, second molar or first premolar and second molar)</u> | <u>Thermocycling, and mechanical loading.</u> | <u>- Mechanical loading: 600 000;</u> <u>= Thermocyclin g: 10⁴.</u> | <u>- Mechanical loading: 50 N;</u> <u>= Thermocycli ng: 6.5° - 60°.</u> | <u>Proximal box (P):</u> <u>- 7 mm span length ≤ 12 mm span length – p = 0.021</u> |

| | | | | | | | | | |
|---------------------------------|--|--|---|----------------------|--|---------------------------------------|---|--|--|
| | | | <u>Proximal and occlusal box (PO)</u> | | | | | | <u>- 12 mm span length < 19 mm span length – p = 0.007</u> |
| | | | | | | | | | <u>C > G – p<0.5</u> |
| <u>Ozcan et al. 2005</u> | <u>Fixed partial denture 3-unit</u> | <u>Reinforced composite resin with glassfibers</u> | <u>n= 7</u> <u>G1: conventional inlay burs</u> <u>G2: SONICSYS approx tips (small)</u> <u>G3: SONICSYS approx tips (large)</u> | <u>no</u> | <u>human mandibular right first premolars and first molars</u> | <u>Storage and thermocycling</u> | <u>- Storage: distilled water at 36 °C for 72 h;</u> <u>= Thermocyclin g: 6000 cycles.</u> | <u>= Thermocycli ng: 5° - 55°</u> | <u>Initial and final failures:</u> <u>G1(842 ± 267 N, 1161 ± 428 N) = G2 (1088 ± 381 N, 1320 ± 380 N) = G3 (1070 ± 280 N, 1557 ± 321 N)</u> <u>p = 0.3</u> |
| <u>Behr et al., 2003</u> | <u>Fixed glass fibre-reinforced molar crowns</u> | <u>Fibre-reinforced system Vectris/Targis</u> | <u>n=8</u> <u>G1: Inner fibre framework.</u> <u>G2: Control group:</u> <u>G3: Inner composite layer</u> | <u>Yes/Impreg um</u> | <u>third human molars</u> | <u>Thermal and mechanical loading</u> | <u>-6000 thermal cycles).</u> <u>-1.2 × 10⁶</u> <u>mastication cycles</u> | <u>5°C/55° C</u> <u>50 N, 1.66 Hz</u> | <u>G1 (1896 N)=G3 (1754 N) > G2 (1509 N). p(<0.05).</u> |
| <u>Rosentritt, et al., 2003</u> | <u>Three-unit FPDs and inlay FPDs.</u> | <u>IPS Vectris/Empress 2, zircon ceramic (Lava) and Vectris/targis</u> | <u>FDP: G1: Vectris/Empress . G2: Zircon. G3: Vectris/targis Inlay FDP: G4: Vectris/Empress . G5: Zircon. G6: Vectris/targis</u> | <u>Yes/Impreg um</u> | <u>human molars</u> | <u>Thermociclyng</u> | <u>5.000 cycles</u> | <u>5°C/55° C</u> | <u>FDP: G1(1400N)>G2(800 N)>G3(350N).</u> <u>Inlay FDP: G5 (1000N) and G6 (14000N)> G4(500N)</u> |
| <u>Song et al., 2003.</u> | <u>Inlay fixed partial dentures</u> | <u>Targis/Vectris system</u> | <u>N=10</u> <u>A) a 7-mm tub-shaped B) an 11-mm tub-shaped C) a 7-mm box-</u> | <u>Yes/Impreg um</u> | <u>Premolars and molars</u> | <u>=</u> | <u>=</u> | <u>=</u> | <u>C (1779N)> A (1368 N)>B (885N)> D (1336N). (P <.001)</u> |

| | | | | | | | | | |
|---------------------------------------|---|--|--|----------------------|---------------------|---|--|--|---|
| <u>shaped D) an 11-mm box-shaped.</u> | | | | | | | | | |
| <u>Kolbeck et al., 2002</u> | <u>Inlay fixed partial dentures (IFPDs) – 3 unit</u> | <u>Polyethylene fiber–reinforced composite.</u> <u>Glass fiber–reinforced composites.</u> <u>All-ceramic material.</u> | <u>n=80</u> <u>G1:Connect/BelleGlass.</u> <u>G2: FibreKor/Conquest Sculpture.</u> <u>G3:</u> <u>Vectris/Targis. G4: Everstick/Sinfony.</u> <u>G5:Empress2</u> | <u>Yes/Impregum</u> | <u>Human molars</u> | <u>Thermal and mechanical loading</u> | <u>-6000 thermal cycles).</u> <u>-1.2 × 10⁶ mastication cycles</u> | <u>5°C/55° C</u> <u>50 N, 1.66 Hz</u> | <u>FibreKor (368N) < Connect/BelleGlass (898 N). Vectris/Targis (723 N).</u> <u>Everstick/Sinfony (634 N) and Empress2 (520 N).</u> |
| <u>Behr et al. 1999</u> | <u>Fixed partial inlay – 3 unit</u> | <u>Fibre-reinforced system Vectris/Targis</u> | <u>N=60</u> <u>G1: box-shaped G2: tub-shaped</u> | <u>No.</u> | <u>=</u> | <u>Thermocycling and mechanical loading</u> | <u>- 6000 thermal cycles</u> <u>-1.2X10⁶ mastication cycles</u> | <u>5°C/55° C/50 N, 1.66 Hz</u> | <u>No significant differences (p= 0.065).</u> |
| <u>Rosentritt et al. 1998</u> | <u>Fiber-reinforced composite (FRC)/ fixed partial dentures (FPDs) 3-unit</u> | <u>Composite resin</u> | <u>N=73</u> <u>-Original.</u> <u>-Repaired A (2400 × 5° C/55° C, 480.000 × 50 N)</u> <u>Repaired B 6000 × 5° C/55° C, 1.2 × 10⁶ × 50 N)</u> | <u>Yes/ Impregum</u> | <u>=</u> | <u>Thermal and mechanical loading</u> | <u>-6000 thermal cycles).</u> <u>-1.2 × 10⁶ mastication cycles</u> | <u>5°C/55° C/50N</u> | <u>Original FPD (1450 N) > repaired A (1000 N) and B (1190 N).</u> <u>(p=0.0026)</u> |

Table V: Risk of Bias of the Studies Considering for the inclusion in the systematic review.

| <u>Author / Year</u> | <u>Sample size calculation</u> | <u>Randomization</u> | <u>Preparation of samples</u> | <u>Aging</u> | <u>Standardization of procedures (ISO)</u> | <u>Operator</u> | <u>Total</u> |
|----------------------------------|--------------------------------|----------------------|-------------------------------|--------------|--|-----------------|--------------|
| <u>Dogan, et al., 2017</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Partiyan et al., 2017</u> | 1 | 1 | 0 | 0 | 2 | 2 | 6 |
| <u>Hussien et al., 2016</u> | 2 | 1 | 0 | 2 | 2 | 2 | 9 |
| <u>Weyhrauch, et al., 2016</u> | 2 | 1 | 1 | 1 | 1 | 2 | 8 |
| <u>Altamimi et. al 2014</u> | 2 | 2 | 0 | 0 | 2 | 2 | 8 |
| <u>Murase et al., 2014</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Taguchi., 2014</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Chaar, et al., 2013</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Eroglu and Gurbulak 2013</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Nie et. al 2013</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Takuma, Y. et al., 2013</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Abou-Madina, et al., 2012</u> | 2 | 1 | 0 | 0 | 2 | 2 | 7 |
| <u>Özcan et al., 2012</u> | 0 | 0 | 0 | 1 | 1 | 0 | 2 |

| | | | | | | | |
|------------------------------------|----------|----------|----------|----------|----------|----------|----------|
| <u>Preis et al., 2012.</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>5</u> |
| <u>Salimi, H. et al., 2012</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>1</u> | <u>6</u> |
| <u>Nothdurft et. al 2011</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Onodera et al., 2011.</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Rosentritt, M. et al., 2011</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>5</u> |
| <u>Mohsen et al., 2010</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Eisenburger et. al. 2008</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Att et al. 2007</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>*Att et al. 2007</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Kohorst et al. 2007</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Larsson et al. 2007</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Xie et al. 2007</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Attia et al 2006</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Pfeiffer et al. 2006</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Rosentritt et al. 2006</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Stiesch-Scholz et al. 2006</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Dyer et al. 2005</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Mitov et. al 2005</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>7</u> |
| <u>Ohlmann et al. 2005</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |

| | | | | | | | |
|--|----------|----------|----------|----------|----------|----------|----------|
| <u>Ozcan et al. 2005</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>1</u> | <u>7</u> |
| <u>Rosentritt et al. 2005</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Sundh et al 2005</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Attia et al., 2004</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>1</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Behr et al., 2003</u> | <u>1</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>2</u> | <u>6</u> |
| <u>Pfeiffer, et al., 2003.</u> | <u>2</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>9</u> |
| <u>Rosentritt. et al., 2003</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>1</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Song et al., 2003.</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>2</u> | <u>9</u> |
| <u>Chitmongkolsuk et al., 2002</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>2</u> | <u>9</u> |
| <u>Kolbeck et al., 2002</u> | <u>1</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>3</u> |
| <u>*Kolbeck et al., 2002</u> | <u>1</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>3</u> |
| <u>Ku et al., 2002</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>8</u> |
| <u>Nakamura et al., 2002</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>2</u> | <u>6</u> |
| <u>Ellakwa et al. 2001</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>1</u> | <u>4</u> |
| <u>Kheradmandan et al., 2001</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>2</u> | <u>2</u> | <u>2</u> | <u>9</u> |
| <u>El-Mowafy et al. 2000.</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>4</u> |
| <u>Koutayas, et al., 2000</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>0</u> | <u>1</u> | <u>3</u> |
| <u>Nohrström et al. 2000</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>3</u> |
| <u>Rosentritt et al. 2000</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>2</u> |
| <u>*Rosentritt et al. 2000</u> | <u>1</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>4</u> |

| | | | | | | | |
|------------------------------|----------|----------|----------|----------|----------|----------|----------|
| <u>Behr et al. 1999</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>5</u> |
| <u>Rosentritt et al.1998</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>5</u> |
| <u>Vallittu et al. 1998</u> | <u>2</u> | <u>1</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>5</u> |
| <u>Scherrer et al. 1996</u> | <u>2</u> | <u>1</u> | <u>1</u> | <u>0</u> | <u>1</u> | <u>1</u> | <u>6</u> |
| <u>Kern et al. 1994</u> | <u>2</u> | <u>2</u> | <u>0</u> | <u>0</u> | <u>1</u> | <u>2</u> | <u>7</u> |

3.3 Characteristics of studies with different materials tested with and without PDL simulation

3.3.1 Metal-ceramic (MC)

For MC without PDL simulation for 3-unit and 4-unit ,one study was found [45]. With PDL simulation, for 3-unit and 4-unit, two studies [40, 42] reported the use of materials such as polyether and gum resin, respectively, to simulate the PDL. With PDL simulation data were not available for single crowns and for inlay-retained FDPs. Thus, the effect of PDL could not be identified for single crowns and inlay-retained FDPs and cantilever made of MC.

3.3.2 All-ceramic (AC)

For AC material without PDL simulation, five studies were available for 4-unit FDPs, where four studies have used yttria-stabilized zirconia as a ceramic material [5,29, 36, 46] and one study using glass-ceramic [21].

For single crowns, only three studies with AC material had PDL simulation [55, 56, 59]. The ceramic materials varied widely among the studies and ceramics such as: Lithium disilicate glass, feldspathic glass ceramic, monolithic zirconia, leucite-reinforced glass ceramic, zirconia-reinforced lithium silicate ceramic (Vita Suprinity, polymer reinforced fine-structure feldspathic ceramic (Vita Enamic).

For inlay-retained FDPs and cantilever the simulation of PDL was observed in all studies with the AC material.

3.3.3 Fiber-reinforced composite (FRC)

Five studies of FDP 3-unit and 4-unit using FRC were found. Of these, only one was without PDL. [38]. For single crowns no studies using FRC were found.

Two studies of the FRC material inlay-retained FDPs and cantilever observed the effect of the PDL simulation [68, 69].

3.6 Composite (C)

No FDP 3-unit and 4-unit studies were found with material C. For Single crowns, only one study used this material [56] and simulated the PDL. All five studies with FRC composite material inlay-retained FDPs and cantilever simulated PDL.

4. DISCUSSION

Teeth are surrounded by the periodontal ligament (PDL) which is a thin membrane consisting of collagen fibers. This ligament provides the attachment of the tooth to the surrounding alveolar bone, and under normal circumstances there is no direct contact between the root and the bone. Forces applied to the crown of the tooth are transmitted to the alveolar bone through this layer, stretching, and compressing the ligament [70]. Different cell types, like fibroblasts, osteocytes and osteoblast, respond to the changes in mechanical environment. This biological environment is tried to be simulated using different materials when testing load-bearing capacity of different materials used for various clinical indications. In this way, an artificial periodontal membrane can be used, as previously described in the literature, to simulate the human periodontal membrane and the physiological mobility of the teeth [48]. In addition, some studies reported that the support relationship of the abutments may influence the in vitro evaluation of fracture resistance (71, 44], thus when this artificial material is used, for example a polyether, represent the alveolar bone relative to a simulated biological "width" of 2 mm, conditions that approximate the clinical situation. In this sense, the objectives of this review were to identify the materials used for this purpose and to clarify whether such simulation would decrease the ultimate strength of the restorations. Unfortunately, data were missing for

some materials and some clinical indications to state whether PDL simulation decreases the results or not. yet, some trend could be observed for decreased results that could not be statistically verified. As for materials interestingly, although metal ceramics are being used for decades, proper number of in vitro tests was not performed with and without PDL. It was also not considered as a control group when comparing AC, FRC or C materials with that of MC.

Some authors preferred to simulate the PDL with polyether [7, 10, 18, 63, 66, 69, 72], others gum resin [25, 42, 56, 73, 74] latex [33, 37], wax [28, 32] or silicone [18, 55] presented an analytical way of predicting significant quantities (stresses, strains, strain-energy breakdown, tooth mobility and the position of the centre of resistance) relating to the horizontal translation of a single-rooted tooth [75]. Followed the work of Haack and Haft (1972) [76] in representing the root of a maxillary central incisor as a paraboloid, surrounded by the ligament. However, the shape of the root can be approximated better by using an elliptical paraboloid. In the analyzed in vitro studies, dipping the roots in these materials simulated the presence of PDL. This simplistic approach considered neither the elastic modulus nor the thickness of the used PDL materials. Certainly, simulation of biological structures in vitro is a challenge. Yet, the arbitrary choice of the PDL materials may not translate the stretching behaviour of this biological structure. Furthermore, since lateral displacement forces are dominated with the thickness of the PDL material, it can be anticipated that the forces would be unfavourable when PDL is thicker. In that respect, failure type analysis could have been an adjunct to the fracture strength values alone in understanding the effect of displacement forces in the presence of PDL. However, although initially intended, no description or the heterogeneous description of failure types and lack of fractography analysis could not allow us to focus on the PDL effect on the failure types.

Overall, regarding to materials for single crowns, fracture strength of FRC was higher than that of AC and MC. This could possibly be attributed to lack of delamination with the FRC as opposed to AC and MC where bilayered ceramics are used in the latter two. Delamination of the veneering ceramic leads to seizing the further load application and thereby, an early failure of the whole reconstruction. In this review, similar results were observed made for 3-unit FDPs where FRC and C presented comparable results being higher than those of all-ceramic and metal ceramic. In principle, metal tends to prevent the tensile stresses for veneering ceramics but when veneering ceramic is chipped or fractured, ultimate failure of the metal is not measured since the universal testing machine stops further loading. For 4-unit FDPs, AC showed higher fracture strength values than those of FRC and C. In such long span FDPs possibly polymeric materials did not stand the bending forces. For inlay-retained FDPs, FRC and AC showed similar results yet not being identified statistically. This kind of indication is highly governed by the adhesion of the cement to the abutment and the restorative material. Better adhesion of resin-based cements to FRC might have compensated for its low flexural strength as opposed to AC.

Ultimate goal in measuring load-bearing capacity of materials is to know clinically whether they could endure chewing forces. Different testing methods and the difficulty in measuring masticatory forces result in a wide range of force values. Stress applied during mastication may range between 441 N and 981 N, 245 N and 491 N, 147 N and 368 N, and 98 N and 270 N in the molar, premolar, canine, and incisor regions, respectively [77]. A restoration should be able to withstand stress to approximately 500 N in the premolar region and 500 N to 900 N in the molar region. The results of this study indicated values lower than 500 N only in C material with PDL simulation (393 N).

Although initially intended, failure type analysis could not be classified in this review due to inconsistency of reporting. In fact, the mode of fracture is a good indicator of the path of crack propagation. In a previous study, the changes in energy levels revealed small failures occurring between 300 N to 500 N and continuing until final failure occurred [65]. Future studies should identify and report failures in a more systematic way perhaps also using acoustic emission (AE) signals from the material [65].

One of the main causes of structural failure in restorative dentistry is often as a consequence of fatigue, although static fracture tests may help to screen the durability of FDPs, cyclic loading could be considered a more clinically relevant testing approach. It has been reported that dental restorations fail more frequently under cyclic loading tests that are well below the ultimate flexural strength of these materials as opposed to the application of a single, relatively higher static load [77]. Repeated stresses can predispose restorations to fail under fatigue. By selecting materials with a lower modulus of elasticity than those of cast metal alloys, stress at the interface can be diminished. However, there is no standard method for cyclic loading tests since the chewing cycles vary in every individual.

The studies on in vitro FDP systems in the dental literature practiced cycling times ranging from 100 to 28×10^6 [17]. It has been previously reported that 2×10^6 cycles correspond to approximately four years of normal occlusal and masticatory activity [77]. The load applied also showed variations between 5 to 100 N. On the other hand, from the technical point of view, the magnitude of the applied load with regard to the highest-level force in a fatigue test, should not exceed 50% of the ultimate strength of the material on trial. Unfortunately, this information was not available in the references that performed static loading after fatigue. For this reason, they were excluded from the selection. Therefore, future studies should incorporate the fatigue

component in the study set-up in order to deduce more clinically relevant information considering the ultimate strength of the material to be tested.

The cement plays an important role on the retention of FDPs on the abutment materials. Abutment material let alone, may further affect the ultimate strength of the FDPs. In this study, abutment materials, namely, metals, polymers, ceramics and tooth substance were all pooled in one group in order to increase the number of selected studies. Whether abutment type affects the fracture strength results needs further focus in future studies.

Clinically, sufficient fracture strength values are not known for durable FDPs. The great variation in testing parameters and testing environment would continue to create the confusion in the dental literature. Since in the future new studies are expected to appear in this field, the following items it's advised be disclosed in in vitro studies:

- The dimensions of the FDP and abutment type, abutment material, cement type and its chemical composition, loading conditions (jig dimensions, type, cross-head speed) should be defined precisely.
- A consensus needs to be made on simulating periodontal ligament material and its thickness.
- The fracture strength data should be presented with confidence intervals, mean, minimum and maximum values.
- At least 6 specimens should be tested in one experimental group.
- Failure types after fracture test should be listed in detail and preferably fractography should be performed.
- Fracture strength results before and after fatigue conditions should be reported.

5. CONCLUSION

From this study, the following could be concluded:

1. Current studies regarding the fracture strength of FDPs made of different materials should be evaluated cautiously considering testing conditions. Some more systematic approach especially regarding the simulation conditions is needed when studying fracture strength of FDPs.
2. PDL simulation seems to show some tendency for decreased fracture strength values.
Yet, it could not be verified statistically because in vitro data with and without PDL in the same clinical conditions are not sufficient.

Acknowledgements

The authors acknowledge Mrs. H. Eschle, University of Zürich, Center for Dental and Oral Medicine, Zürich, Switzerland, for her assistance with the library facilities and Mrs. M. Roos, from the Division of Biostatistics, Institute of Social and Preventive Medicine, University of Zurich, Switzerland for her support with the statistical analysis.

Conflict of interest

The authors declare that they have no conflict of interest.

6. REFERENCES

- 1- DIN EN ISO 22674 norm. Metallic materials for fixed and removable restorations and application, DIN, German Institute for norming.
- 2- Vallittu P. The effect of glass fiber reinforcement on the fracture resistance of a provisional fixed partial denture. J Prosthet Dent. 1998 Feb;79(2):125-30.

- 3- Nohrström T, Vallittu P, Yli-Urpo A. The effect of placement and quantity of glass fibers on the fracture resistance of interim fixed partial dentures. Int J Prosthodont. 2000 Jan-Feb;13(1):72-8.
- 4- Kiliçarslan M, Kedici P, Kücükmesmen H, Uludag B, 2004. In vitro fracture resistance of posterior metal-ceramic and all-ceramic inlay-retained resin-bonded fixed partial dentures. J Prosthet Dent. 2004 Oct;92(4):365-70.
- 5- Sundh A, Molin M, Sjögren G. Fracture resistance of yttrium oxide partially-stabilized zirconia all-ceramic bridges after veneering and mechanical fatigue testing. Dent Mater. 2005 May;21(5):476-82.
- 6- Bhakta S, van Noort R, Cardew G. Improved retention of anterior cantilever resin-bonded prostheses by design alteration: an experimental and finite element study. J Prosthet Dent. 2006 Mar;95(3):209-17
- 7- Rosentritt M, Behr M, Gebhard R, Handel G. Influence of stress simulation parameters on the fracture strength of all-ceramic fixed-partial dentures. Dent Mater. 2006 Feb;22(2):176-82.
- 8- Garoushi S, Vallittu P, Lassila L. Use of short fiber-reinforced composite with semi-interpenetrating polymer network matrix in fixed partial dentures. J Dent. 2007 May;35(5):403-8.
- 9- Ohlmann B, Schmitter M, Gabbert O, Rammelsberg P. Fracture load of fixed partial dentures anchored by composite inlays. Am J Dent. 2007 Dec;20(6):405-10.
- 10- Kolbeck C, Behr M, Rosentritt M, Handel G. Fracture force of tooth-tooth and implant-tooth-supported all-ceramic fixed partial dentures using titanium vs. customised zirconia implant abutments. Clin Oral Implants Res. 2008 Oct;19(10):1049-53

- 11- Kumbuloglu O, Özcan M, User A. Fracture strength of direct surface-retained fixed partial dentures: effect of fiber reinforcement versus the use of particulate filler composites only. Dent Mater J. 2008 Mar;27(2):195-202.
- 12- Balkenhol M, Köhler H, Orbach K, Wöstmann B. Fracture toughness of cross-linked and non-cross-linked temporary crown and fixed partial denture materials. Dent Mater. 2009 Jul;25(7):917-28.
- 13- Fahmy N, Sharawi A. Effect of two methods of reinforcement on the fracture strength of interim fixed partial dentures. J Prosthodont. 2009 Aug;18(6):512-20.
- 14- Fischer J, Stawarczyk B, Trottmann A, Hämmerle C. Impact of thermal properties of veneering ceramics on the fracture load of layered Ce-TZP/A nanocomposite frameworks. Dent Mater. 2009 Mar;25(3):326-30.
- 15- Inan O, Secilmis A, Eraslan O. Effect of pontic framework design on the fracture resistance of implant-supported all-ceramic fixed partial dentures. J Appl Oral Sci. 2009 Sep-Oct;17(5):533-8.
- 16- Stewart R, Staab G. Cross-sectional design and fatigue durability of cantilevered sections of fixed implant-supported prostheses. J Prosthodont. 1995 Sep;4(3):188-94.
- 17- Rosentritt M, Behr M, Leibrock A, Handel G, Friedl K, 1998. Intraoral repair of fiber-reinforced composite fixed partial dentures. J Prosthet Dent. 1998 Apr;79(4):393-8.
- 18- Rosentritt M, Behr M, Lang R, Handel G. Experimental design of FPD made of all-ceramics and fibre-reinforced composite. Dent Mater. 2000 May;16(3):159-65.
- 19- Ellakwa A, Shortall A, Shehata M, Marquis P. The influence of fibre placement and position on the efficiency of reinforcement of fibre reinforced composite bridgework. J Oral Rehabil. 2001 Aug;28(8):785-91.

- 20- Ku C, Park S, Yang H. Comparison of the fracture strengths of metal-ceramic crowns and three ceromer crowns. J Prosthet Dent. 2002 Aug;88(2):170-5.
- 21- Nakamura T, Ohyama T, Imanishi A, Ishigaki S. Fracture resistance of pressable glass-ceramic fixed partial dentures. J Oral Rehabil. 2002 Oct;29(10):951-5.
- 22- Behr M, Rosentritt M, Sikora M, Karl P, Handel G. Marginal adaptation and fracture resistance of adhesively luted glass fibre-composite reinforced molar crowns with different inner crown surfaces. J Dent. 2003 Sep;31(7):503-8.
- 23- Partiyan A, Osman E, Rayyan MM, Aboushelib M, Ibrahim A, Jimbo R. Murase. Fracture resistance of three-unit zirconia fixed partial denture with modified framework. Odontology. 2017 Jan;105(1):62-67.
- 24- Murase T, Nomoto S, Sato T, Shinya A, Koshihara T, Yasuda H. Effect of connector design on fracture resistance in all-ceramic fixed partial dentures for mandibular incisor region. Bull Tokyo Dent Coll. 2014;55(3):149-55.
- 25- Chaar MS1, Witkowski S, Strub JR, Att W. Eroglu and Gurbulak. Effect of veneering technique on the fracture resistance of zirconia fixed dental prostheses. J Oral Rehabil. 2013 Jan;40(1):51-9.
- 26- Eroglu Z, Gurbulak AG. Fatigue behavior of zirconia-ceramic, galvano-ceramic, and porcelain-fused-to-metal fixed partial dentures. J Prosthodont. 2013;22(7):516-22.
- 27- Takuma Y1, Nomoto S, Sato T, Sugihara N. Effect of framework design on fracture resistance in zirconia 4-unit all-ceramic fixed partial dentures. Bull Tokyo Dent Coll. 2013;54(3):149-56
- 28- Preis V, Behr M, Hahnel S, Handel G, Rosentritt M. In vitro failure and fracture resistance of veneered and full-contour zirconia restorations. J Dent. 2012 Nov;40(11):921-8.

- 29- Salimi H, Mosharraf R, Savabi O. Effect of framework design on fracture resistance of zirconium oxide posterior fixed partial dentures. Dent Res J (Isfahan). 2012;9(6):764-9.
- 30- Nothdurft FP, Merker S, Pospiech PR. Fracture behaviour of implant-implant- and implant-tooth-supported all-ceramic fixed dental prostheses utilising zirconium dioxide implant abutments. Clin Oral Investig. 2011;15(1):89-97.
- 31- Onodera K, Sato T, Nomoto S, Miho O, Yotsuya M. Effect of connector design on fracture resistance of zirconia all-ceramic fixed partial dentures. Bull Tokyo Dent Coll. 2011;52(2):61-7.
- 32- Rosentritt M, Behr M, Scharnagl P, Handel G, Kolbeck C. Influence of resilient support of abutment teeth on fracture resistance of all-ceramic fixed partial dentures: an in vitro study. Int J Prosthodont. 2011 Sep-Oct;24(5):465-8.
- 33- Eisenburger M, Riechers J, Borchers L, Stiesch-Scholz M. Load-bearing capacity of direct four unit provisional composite bridges with fibre reinforcement. J Oral Rehabil. 2008 May;35(5):375-81.
- 34- Att W, Grigoriadou M, Strub J. ZrO₂ three-unit fixed partial dentures: comparison of failure load before and after exposure to a mastication simulator. J Oral Rehabil. 2007 Apr;34(4):282-90.
- 35- *Att W, Stamouli K, Gerds T, Strub J. Fracture resistance of different zirconium dioxide three-unit all-ceramic fixed partial dentures. Acta Odontol Scand. 2007 Feb;65(1):14-21.
- 36- Larsson C, Holm L, Lovgren N, Kokubo Y, Vult von Steyern P. Fracture strength of four-unit Y-TZP FPD cores designed with varying connector diameter. An in-vitro study. J Oral Rehabil. 2007;34(9):702-9.

- 37- Kohorst P, Herzog T, Borchers L, Stiesch-Scholz M. Load-bearing capacity of all-ceramic posterior four-unit fixed partial dentures with different zirconia frameworks. Eur J Oral Sci. 2007 Apr;115(2):161-6.
- 38- Pfeiffer P, Grube L. Effect of pontic height on the fracture strength of reinforced interim fixed partial dentures Dent Mater. 2006 Dec;22(12):1093-7.
- 39- Stiesch-Scholz M, Schulz K, Borchers L. In vitro fracture resistance of four-unit fiber-reinforced composite fixed partial dentures. Dent Mater. 2006 Apr;22(4):374-81.
- 40- Rosentritt M, Behr M, Brückner H, Handel G. Composite veneering of metal based fixed partial dentures. J Oral Rehabil. 2005 Aug;32(8):614-9.
- 41- Pfeiffer P, Grube L. In vitro resistance of reinforced interim fixed partial dentures. J Prosthet Dent. 2003 Feb;89(2):170-4.
- 42- Chitmongkolsuk S, Heydecke G, Stappert C, Strub J. Fracture strength of all-ceramic lithium disilicate and porcelain-fused-to-metal bridges for molar replacement after dynamic loading Eur J Prosthodont Restor Dent. 2002 Mar;10(1):15-22.
- 43- Kolbeck C, Rosentritt M, Behr M, Lang R, Handel G. In vitro study of fracture strength and marginal adaptation of polyethylene-fibre-reinforced-composite versus glass-fibre-reinforced-composite fixed partial dentures. J Oral Rehabil. 2002 Jul;29(7):668-74..
- 44- Kheradmandan S, Koutayas S, Bernhard M, Strub J. Fracture strength of four different types of anterior 3-unit bridges after thermo-mechanical fatigue in the dual-axis chewing simulator. J Oral Rehabil. 2001 Apr;28(4):361-9.
- 45- El-Mowafy O, Rubo M. Retention of a posterior resin-bonded fixed partial denture with a modified design: an in vitro study. Int J Prosthodont. 2000 Sep-Oct;13(5):425-31.
- 46- Eroglu Z, Gurbulak AG. Fatigue behavior of zirconia-ceramic, galvano-ceramic, and porcelain-fused-to-metal fixed partial dentures. J Prosthodont. 2013;22(7):516-22.

- 47- Koutayas S, Kern M, Ferraresso F, Strub J. Influence of design and mode of loading on the fracture strength of all-ceramic resin-bonded fixed partial dentures: an in vitro study in a dual-axis chewing simulator. J Prosthet Dent. 2000 May;83(5):540-7.
- 48- Kern M, Fechtig T, Strub J. 1994. Influence of water storage and thermal cycling on the fracture strength of all-porcelain, resin-bonded fixed partial dentures. J Prosthet Dent. 1994 Mar;71(3):251-6.
- 49- Dogan DO, Gorler O, Mutaf B, Ozcan M, Eyuboglu GB, Ulgey M. Fracture Resistance of Molar Crowns Fabricated with Monolithic All-Ceramic CAD/CAM Materials Cemented on Titanium Abutments: An In Vitro Study. J Prosthodont. 2017 Jun;26(4):309-314.
- 50- Hussien AN, Rayyan MM, Sayed NM, Segaan LG, Goodacre CJ, Kattadiyil MT. Effect of screw-access channels on the fracture resistance of 3 types of ceramic implant-supported crowns. J Prosthet Dent. 2016 Aug;116(2):214-20.
- 51- Weyhrauch M, Igiel C, Scheller H, Weibrich G, Lehmann KM. Fracture Strength of Monolithic All-Ceramic Crowns on Titanium Implant Abutments. Int J Oral Maxillofac Implants. 2016;31(2):304-9.
- 52- Altamimi AM, Tripodakis AP, Eliades G, Hirayama H. Comparison of fracture resistance and fracture characterization of bilayered zirconia/fluorapatite and monolithic lithium disilicate all ceramic crowns. Int J Esthet Dent. 2014;9(1):98-110.
- 53- Taguchi K, Komine F, Fushiki R, Blatz MB, Kamio S, Matsumura H. Fracture resistance of single-tooth implant-supported zirconia-based indirect composite-layered molar restorations. Clin Oral Implants Res. 2014;25(8):983-91.
- 54- Nie EM, Chen XY, Zhang CY, Qi LL, Huang YH. Influence of masticatory fatigue on the fracture resistance of the pulpless teeth restored with quartz-fiber post-core and crown. Int J Oral Sci. 2012;4(4):218-20.

- 55- Abou-Madina MM1, Özcan M, Abdelaziz KM, Attia A, Abdelaziz K, Freitag S, Kern M. Influence of resin cements and aging on the fracture resistance of IPS e.max press posterior crowns. Int J Prosthodont. 2012 Jan-Feb;25(1):33-5.
- 56- Attia A, Abdelaziz KM, Freitag S, Kern M. Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns. J Prosthet Dent. 2006;95(2):117-23.
- 57- Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns. J Prosthet Dent. 2006 Feb;95(2):117-23.
- 58- Mitov G, Anastassova-Yoshida Y, Nothdurft FP, von See C, Pospiech P. Influence of the preparation design and artificial aging on the fracture resistance of monolithic zirconia crowns. J Adv Prosthodont. 2016;8(1):30-6.
- 59- Attia A, Kern M. Influence of cyclic loading and luting agents on the fracture load of two all-ceramic crown systems. J Prosthet Dent. 2004 Dec;92(6):551-6.
- 60- *Rosentritt M, Plein T, Kolbeck C, Behr M, Handel G. In vitro fracture force and marginal adaptation of ceramic crowns fixed on natural and artificial teeth. Int J Prosthodont. 2000 Sep-Oct;13(5):387-91.
- 61- Scherrer S, De Rijk W, Belser U. Fracture resistance of human enamel and three all-ceramic crown systems on extracted teeth. Int J Prosthodont. 1996 Nov-Dec;9(6):580-5.
- 62- Mohsen C. Fracture resistance of three ceramic inlay-retained fixed partial denture designs. An in vitro comparative study. J Prosthodont. 2010 Oct;19(7):531-5.
- 63- Xie Q, Lassila L, Vallittu P. Comparison of load-bearing capacity of direct resin-bonded fiber-reinforced composite FPDs with four framework designs. J Dent. 2007 Jul;35(7):578-82.
- 64- Dyer S, Lassila L, Alander P, Vallittu P. Static strength of molar region direct technique glass fibre-reinforced composite fixed partial dentures. J Oral Rehabil. 2005 May;32(5):351-7.

- 65- Özcan M, Breuklander M, Vallittu P. The effect of box preparation on the strength of glass fiber-reinforced composite inlay-retained fixed partial dentures. J Prosthet Dent. 2005 Apr;93(4):337-45.
- 66- Rosentritt M, Behr M, Handel G. Fixed partial dentures: all-ceramics, fibre-reinforced composites and experimental systems. J Oral Rehabil. 2003 Sep;30(9):873-7.
- 67- Song H, Yi Y, Cho L, Park D. Effects of two preparation designs and pontic distance on bending and fracture strength of fiber-reinforced composite inlay fixed partial dentures. J Prosthet Dent 2003;90:347-353.
- 68- Kolbeck C, Rosentritt M, Behr M, Lang R, Handel G. In vitro examination of the fracture strength of 3 different fiber-reinforced composite and 1 all-ceramic posterior inlay fixed partial denture systems. J Prosthodont. 2002 Dec;11(4):248-53.
- 69- Behr M, Rosentritt M, Leibrock A, Schneider-Feyrer S, Handel G. In-vitro study of fracture strength and marginal adaptation of fibre-reinforced adhesive fixed partial inlay dentures. J Dent. 1999 Feb;27(2):163-8.
- 70- Van Schepdael A, Geris L, Van der Sloten J. Analytical determination of stress patterns in the periodontal ligament during orthodontic tooth movement. Med Eng Phys 2013;35:403-410.
- 71- Carrier D, Kelly J. In-Ceram failure behavior and core-veneer interface quality as influenced by residual infiltration glass. J Prosthodont 1995;4:237-242.
- 72- Rosentritt M, Siavikis G, Behr M, Kolbeck C, Handel G. Approach for valuating the significance of laboratory simulation. J Dent. 2008 Dec;36(12):1048-53.
- 73- Att W, Grigoriadou M, Strub J. ZrO₂ three-unit fixed partial dentures: comparison of failure load before and after exposure to a mastication simulator. J Oral Rehabil. 2007 Apr;34(4):282-90.

- 74- Att W, Stamouli K, Gerds T, Strub J. Fracture resistance of different zirconium dioxide three-unit all-ceramic fixed partial dentures. Acta Odontol Scand. 2007 Feb;65(1):14-21.
- 75- Provatidis CG. A comparative FEM-study of tooth mobility using isotropic and anisotropic models of the periodontal ligament. Finite element method. Med Eng Phys. 2000 Jun;22(5):359-70.
- 76- Haack DC, Haft EE. An analysis of stresses in a model of the periodontal ligament. Int J Eng Sci 1972;10:1093-1106.
- 77- Baldissara P, Özcan M, Melilli D, Valandro LF. Effect of cyclic loading on fracture strength and microleakage of a quartz fiber dowel with different adhesive, cement and resin core material combinations. Minerva Stomatol. 2010 Jul-Aug;59(7-8):407-14.

CAPTIONS TO FIGURES:

Figure 1: The PRISMA flowchart showing the study selection process.



Records identified through database searching (PubMed)
(n = 1559)



Records after duplicate removed
(n=744)



Excluded records based on titles and abstracts
(n=619)

Full-text articles
(n=125)



Studies included in manual search: (n=4)

Deleted records based on risk of bias: (n=9)

Deleted records based on full-text reading: (n=63)

Studies included in systematic review
(n=57)